Proceedings of the 8th Academic Sessions, University of Ruhuna 2010
Vol. 8 pgs 115 – 122

BF - 07

Properties of masonry blocks manufactured with crushed demolition waste

Subashi, G.H.M.J., Wasantha, P.L.P., Jayasuriya, J.P.B. and Kandage, J.D.

Department of Civil and Environmental Engineering, Faculty of Engineering, University of Ruhuna, Hapugala, Galle, Sri Lanka.

✉ subashi@cee.ruh.ac.lk

Abstract

Solid waste generated from demolition of old buildings are generally used for land filling. However, the demolition waste which consists of burnt clay brick particles may have appreciable properties to reuse as a civil engineering construction material. In this study an attempt was made to utilize crushed demolition waste as aggregates in the manufacture of masonry blocks. Structural and thermal properties of the masonry block made with crushed demolition waste were also investigated and compared with that of the conventional cement-aggregate blocks.

Construction and demolition waste was crushed and sieved to find the particle size distribution. A well graded sample of crushed demolition wastes with different maximum particle sizes was mixed with cement and water at the volume rate of cement: crushed demolition waste: water is 1:9:6, respectively.

Structural properties of the blocks were investigated by conducting laboratory experiments. Thermal properties of the blocks were investigated by comparing the variation of indoor temperature in two model houses constructed with the cement blocks manufactured with crushed wastes due to the demolition of existing buildings and the conventional cement-aggregate blocks. It was found that the cement blocks, where crushed demolition waste was used are thermally more comfort than the conventional cement-aggregate blocks. The block manufactured with crushed demolition waste also has adequate compressive strength and water absorption ratio to use as masonry blocks.

Introduction

Construction and demolition waste becomes one of the largest waste flows in Sri Lanka, recently, due to the tsunami in 2004 and 30 year of war. However, in Sri Lanka, construction and demolition waste is not popular as a recyclable material. The general practice is to deliver these wastes to landfills or reclamation sites for disposal due to the absence of markets for their recycled form. Since the quantity pertaining to these wastes is significantly high, a large portion of landfills is required when disposing. With the limited space available for landfills in Sri Lanka, there is an immediate need to explore the possible reusing options for these wastes, possibly as a civil engineering material.

Reusing of large amount of solid waste as a civil engineering material will be an important step to improve the sustainability. Since this method allows reusing materials, it will also minimize the impacts on environment due to extraction of raw materials such as clay and aggregates.

A greater percentage of these construction and demolition waste consists of burnt clay bricks. Since it contains more burnt brick particles it will provide more thermal comfort in building indoor environments when utilized as aggregates in the manufacturing of masonry blocks.

Currently, Cement-aggregate blocks are increasingly used for construction of buildings in Sri Lanka. Due to poor thermal performance of Cement-aggregate block, it could lead to unacceptable temperature rise in indoor environment of buildings and finally will lead to more energy consumption to ensure the thermal comfort (Peavy *et al.*, 1973).

However, solid masonry walls have a favorable rate of heat transfer because of their greater heat storage capacity, which is sometimes referred as thermal mass or capacitive insulation (Jayasinghe and Attalage, 1999). Thermal mass is the ability to store heat. Blocks should absorb heat in the daytime and slowly release the heat in the nighttime. When blocks are absorbing the heat, it will help to maintain a low temperature level of indoor environment throughout a day in a country like Sri Lanka, where high diurnal temperature variation is inherent. Over a 24 hours period, early morning usually has the lowest temperature while the early afternoon usually has the highest temperature. For an example, in the southern part of Sri Lanka, where the study was conducted, the diurnal temperature ranges 25^0C in morning to 32^0C in afternoon in warmer months of March and April (Department of Meteorology, Sri Lanka). In tropical countries, buildings with high thermal mass are common (Heathcote, 2007).

In this study, an attempt was made to utilize crushed demolition waste as aggregates in the manufacture of masonry blocks. The main objective of this investigation was to provide a viable option for the use of crushed demolition waste in Sri Lanka. The compressive strength, water absorption and thermal behavior were determined for the blocks developed with crushed demolition waste. These properties were compared with the properties of Cement-aggregate blocks, which are currently used for construction of buildings.

Materials and Methods

Preparation of cement-crushed demolition waste block

A masonry wall was crushed manually using a hammer to produce crushed demolition waste. Crushed demolition waste mainly contains brick, metal and a considerable amount of adhered mortar. For the study, three different samples of crushed demolition wastes were selected based on sieve analysis. Sample 1 has a maximum particle size of 11.2 mm while Sample 2 has a maximum particle size of 13.2 mm. Sample 3 has a maximum particle size of 16 mm. Grading curve for each sample was obtained to ensure that the particle size distribution is in the "Well Graded" region according to the Unified Soil Classification System (USCS).

Each sample was mixed with Ordinary Portland Cement (OPC) and water at the volume rate of cement: crushed demolition waste: water is 1:9:6. Cement was selected as bonding material because it is presently utilizing for block production and commercially available in construction field. Blocks were cast using a normal cement-block manufacturing machine (Figure 1a). The shape and the size of the block were selected as most commonly used and commercially available shape of solid blocks and size: 360 mm x 100 mm x 170 mm (Figure 1b).

Figure 1: (a) - Block manufacturing machine (b) - Cement-crushed demolition waste block

Compressive strength

Compressive strength of blocks was tested using the Concrete Compression Machine available in Building Materials and Construction Laboratory, University of Ruhuna (Figure 2). The block with sieve size which gives the maximum compressive strength was selected for further investigation of strength characteristics and thermal performances. Compressive strength of Cement-crushed demolition waste block was compared with the compressive strength of conventional cement-aggregate blocks. Five blocks from each block type were tested and the average compressive strength values were obtained.

Figure 2: Concrete compression machine

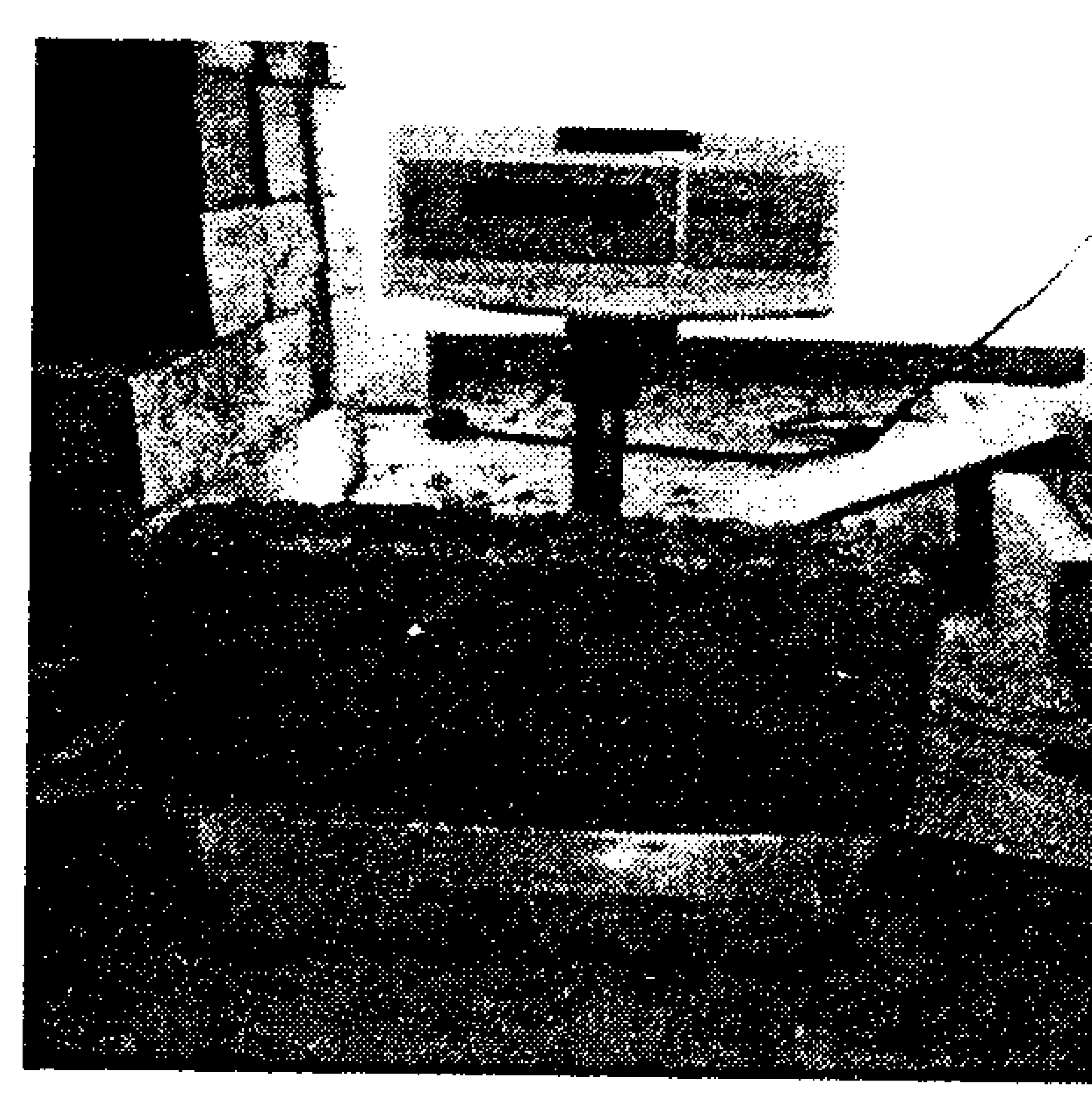

Figure 3: Measuring the weight of a block

Water absorption

Water absorption ratio of blocks was determined by using the weight of a block with dry condition and saturated condition. Three samples of each block type (i.e., Cement-aggregate blocks and Cement-crushed demolition waste blocks) were used for the water absorption test. The sample blocks were kept in an oven with 105°C, for 24 hours and the weights were measured (Figure 3). The same blocks were immersed in water for the period of 24 hours and the weights were measured. Water absorption ratio for each individual sample was determined and average values are presented.

Thermal performance

Thermal behavior of blocks was investigated by comparing the variation of indoor temperature in two model houses: one was constructed with Cement-aggregate blocks and the other one was constructed with Cement-crushed demolition waste blocks for all four walls (Figure 4). The thickness of Cement-crushed demolition waste block wall and Cement-aggregate block wall were equal of 100 mm. No plaster was applied on any side of walls. The size of both model houses was the same; floor area was 1.0 m x 1.0 m and the height was 1.0 m. Identical conditions (i.e., building orientation, building size, roof and floor materials, size and orientation of openings) were provided for both model houses except the walling material. For both model houses, cement fiber sheets were used for roofing. The floors were cement-rendered.

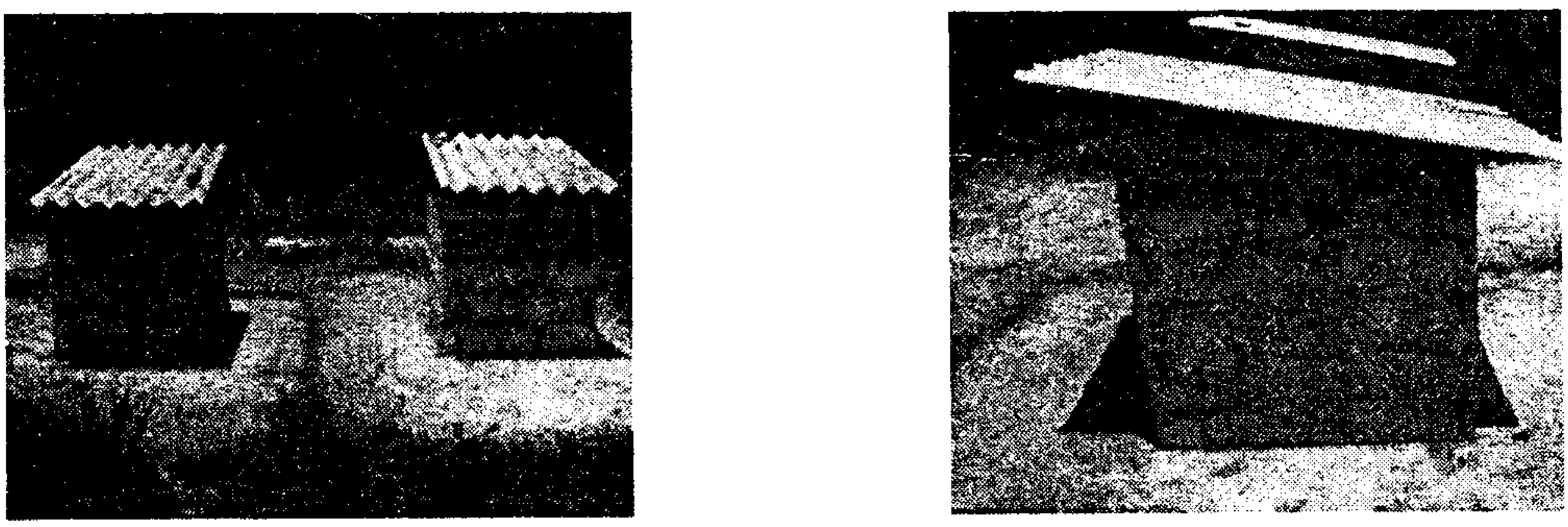

Figure 4: Physical models of model houses

Temperatures were measured throughout a day in April to monitor the thermal behavior of two block materials. The weather condition on this particular day was a sunny day. Walls of both model houses were exposed to direct sunlight. Outdoor air temperature, Indoor air temperature, Outdoor block surface temperature and Indoor block surface temperature were recorded for 15 minutes intervals.

Results

Compressive strength

Average 28 day compressive strength of blocks with different maximum particle sizes is compared in Table 1.

Table 1: Average compressive strengths for different samples

Sample Identity	Sieve size (mm)	Average Strength (N/mm^2)
Sample 1	11.2	2.285
Sample 2	13.2	3.355
Sample 3	16.0	2.171

The effect of maximum particle size on average 28 days compressive strength is compared in Figure 5. It can be seen that, crushed demolition waste with particles size less than 13.8 mm combining with well graded particle size distribution (according to the Unified Soil Classification System (USCS)) gives the maximum compressive strength. The compressive strength of Cement-crushed demolition waste block was compared with the compressive strength of Cement-aggregate block in Table 2.

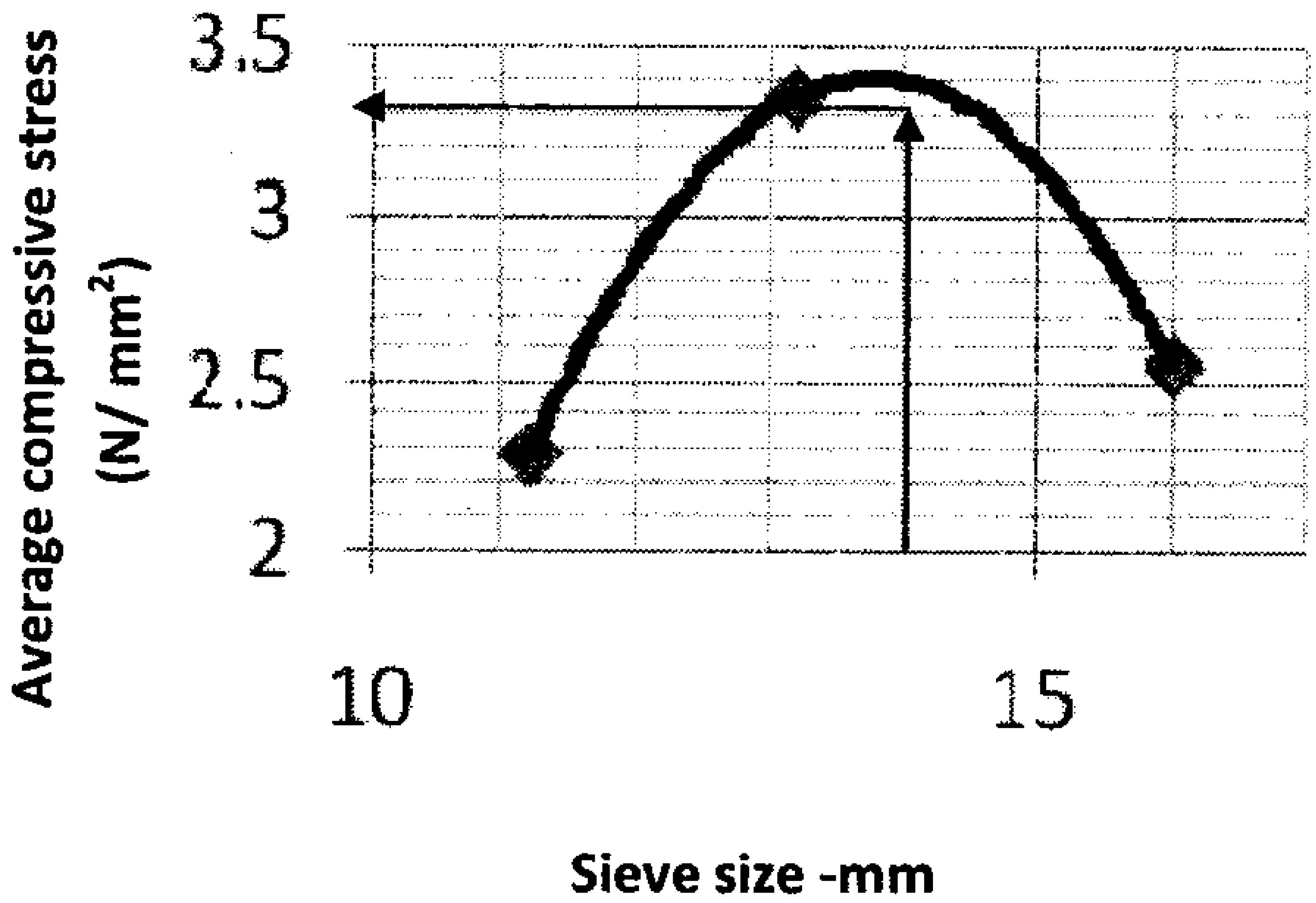

Figure 5: Variation of average compressive stress with sieve size

Table 2: Average 28 day compressive strength of blocks

Block type	Compressive strength (N/ mm^2)
Cement-crushed demolition waste block	3.40
Cement-aggregate block	2.75

It is evident that the compressive strength of Cement-crushed demolition waste blocks is greater than the compressive strength of Cement-aggregate blocks.

Water absorption

Water absorption ratio of Cement-crushed demolition waste block and Cement-aggregate block are compared in Table 3.

Table 3: Comparison of water absorption ratio

Block type	Water absorption (%)
Cement-crushed demolition waste block	12.13
Cement-aggregate block	7.22

Water absorption ratio of Cement-crushed demolition waste block is higher than that of Cement-aggregate block.

Thermal performance

Variation of Indoor air temperature with time between two model houses was compared in Figure 6. During the daytime, Cement-aggregate block shows higher indoor air temperature compared with Cement-crushed demolition waste blocks.

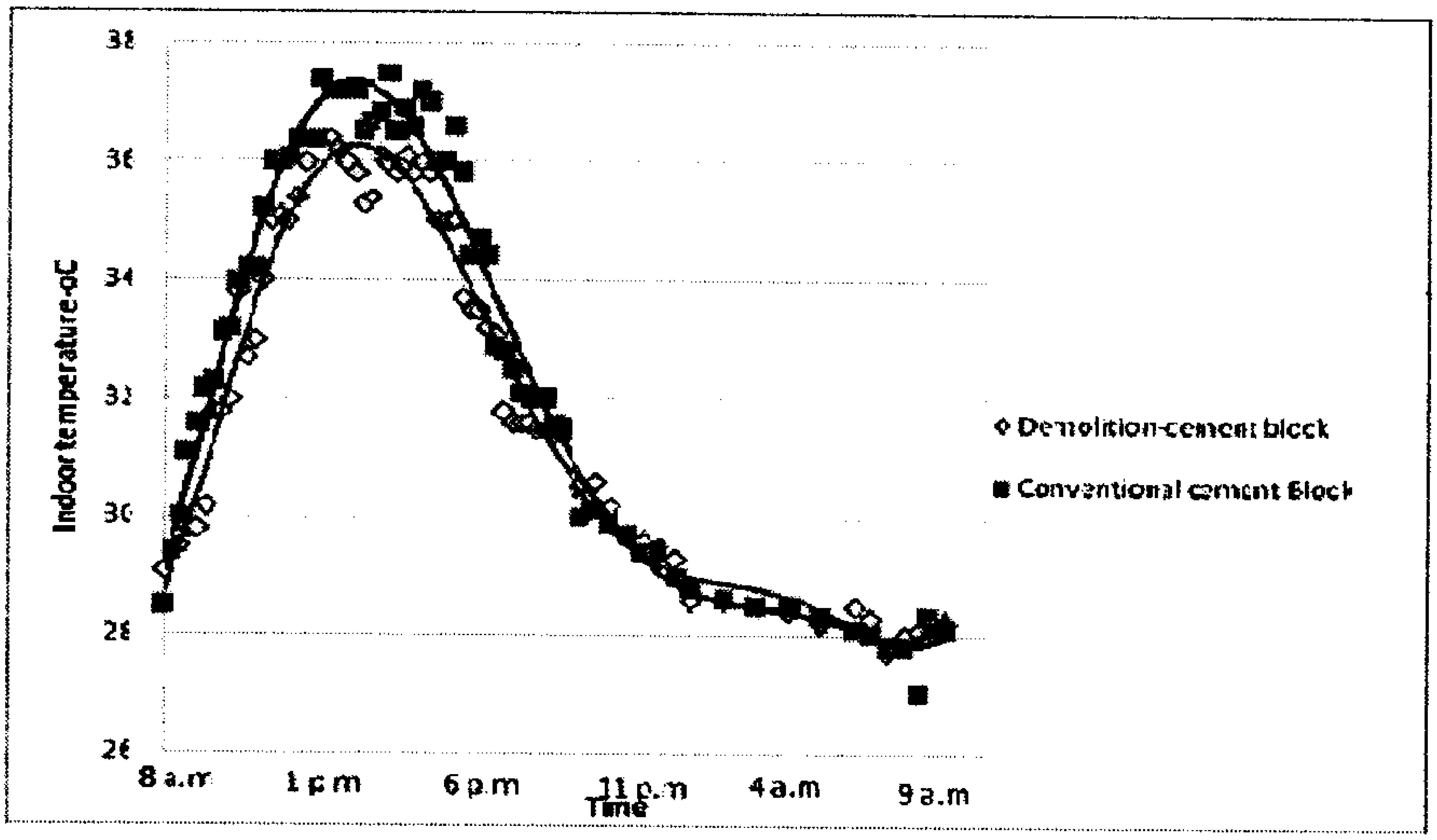

Figure 6: Variation of indoor temperature with time

Under the same condition, it was found that Outdoor surface temperature of all four walls of both model houses was the same. The difference in outdoor and indoor surface temperature variation for two different materials was compared in Figure 7. Compared to the Cement-aggregate blocks, Cement-crushed demolition waste block shows greater difference in outdoor and indoor surface temperature.

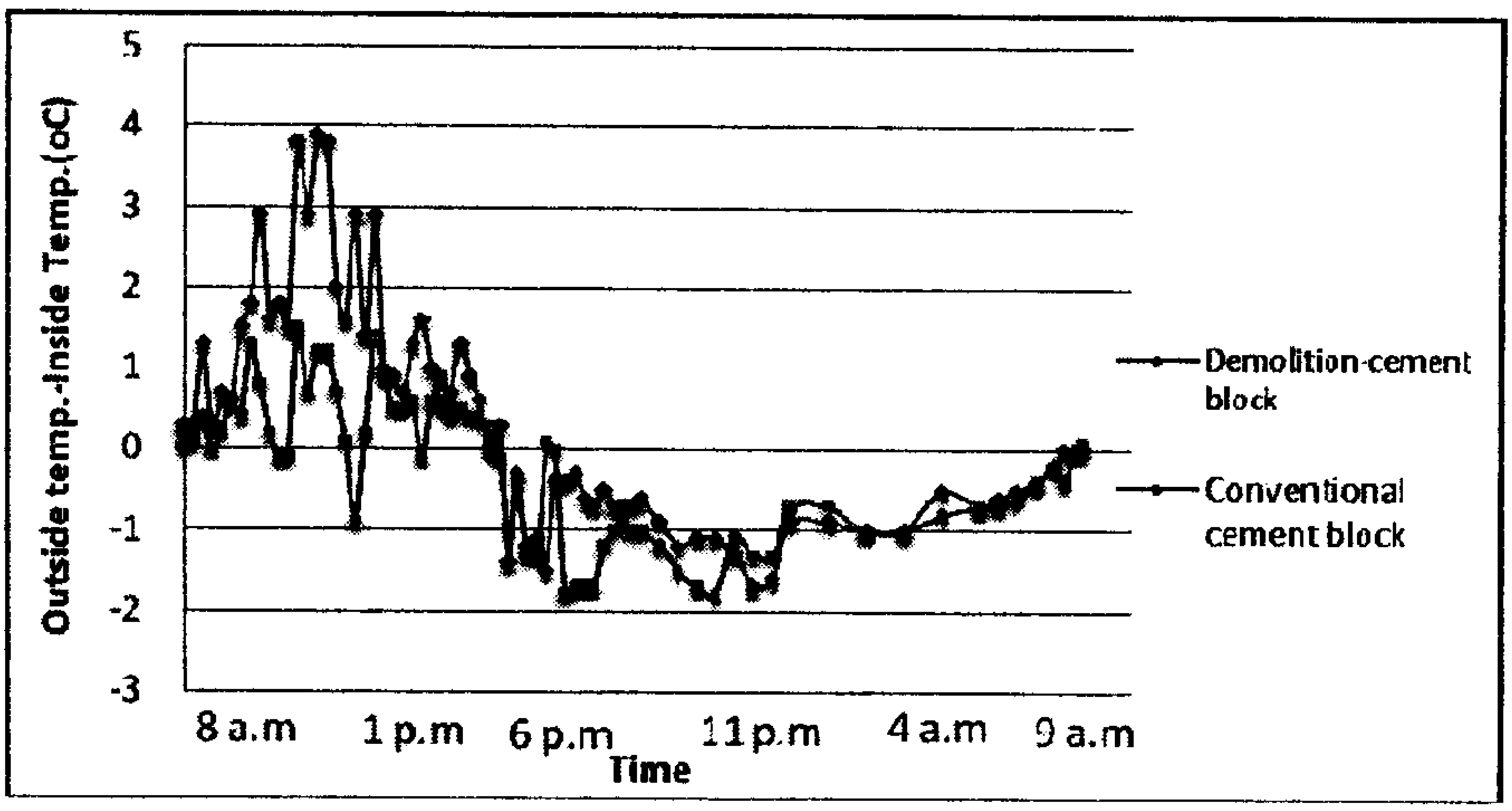

Figure 7: The difference in (Outdoor-Indoor) surface temperature with time

Discussion

Structural properties

Use of crushed demolition waste as replacement of aggregate slightly increases the compressive strength of masonry blocks (Table 2). A possible reason can be attributed to the proper selection of particle sizes: well graded particle size distribution of crushed demolition waste might increase the bonding between burnt clay particles and cement.

However, Cement-crushed demolition waste block has shown a highly water absorbent behavior compared to Cement-aggregate blocks (Table 3). This can be expected since it consists of more burnt clay particles, which would anyway absorb some water. According to the BS 5628-1:2005 (Anonymous, 2005) a water absorption ratio of about 12% is acceptable.

Thermal properties

The temperature measured for model houses indicated that Cement-crushed demolition waste block maintains greater difference in outdoor and indoor temperature during the daytime, when the outdoor temperature is the highest. This indicates that Cement-crushed demolition waste block shows the similar performance of a high thermal mass and has the ability to absorb heat during the daytime. Thermal comfort of a building is significantly affected by the amount of heat that transmitted into a building through walls, roof, ceiling and windows (Arora, 2000). The amount of heat transmitted into a building largely depends on properties of walling, roofing and ceiling materials (Szokolay, 1991). To reduce the cooling load in buildings, it is important to construct walls with a low thermal conductivity construction material. Cement-crushed demolition waste block, which shows high thermal mass performance, has an advantage as a walling material as it reduces indoor temperature. This will improve indoor thermal comfort.

Maximum difference in indoor air temperature between two model houses is about 1.5°C during the day time (Figure 5). However, at the beginning of the late night (i.e., about 10.p.m) the Cement-crushed demolition waste blocks might start to release the heat, which is stored during the daytime. Meanwhile, Cement-aggregate blocks maintain a slightly lower temperature at nighttime compared to the Cement-crushed demolition waste block.

Conclusion

Crushed demolition waste can be utilized as aggregates in the manufacture of masonry blocks. Alternative to aggregates as a material to manufacture masonry blocks is very desirable to improve the sustainability. This masonry block shows that indoor environments more thermally comfortable than conventional cement-aggregate blocks with an adequate level of strength characteristics. Eventually, it is lead to conserve energy by reducing the energy consumption for artificial thermal comfort.

Acknowledgement

The authors wish to express their special thanks to Research Committee of University of Ruhuna for providing necessary funds to carry out the research work presented in this paper.

References

Anonymous (2005) BS 5628-1- Code of practice for the use of masonry, Part 1: Structural use of unreinforced masonry. British Standards Institution.

Arora C. P. (2000). Refrigeration and air conditioning. 2nd ed.. Singapore: Tata McGraw-Hill Inc.

Heathcote K.A. (2007). Thermal performance of a mud brick test building. Proceedings of International Symposium on Earthen Structures. Indian Institute of science, Bangalore.
Jayasinghe, M.T.R. and Attalage R.A. (1999). Comfort conditions for built environments in Sri Lanka, Engineer, Journal of Institution of Engineers, Sri Lanka, 29(1), 12-23.
Metrological reports, Department of Meteorology, Sri Lanka.
Peavy, B.A., Powell, F.J. and Burch, D.M. (1973). Dynamic thermal performance of an experimental masonry building. Building Science Series 45. U.S. National Bureau of Standards, Washington.
Szokolay S.V.(1991). "Heating and cooling of buildings". New York, Van Hostrand Reinhold.